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(54) IMPROVEMENTS IN OR RELATING TO HIGH SPEED TEMPERATURE CONTROL SYSTEMS

(71) We, HAWKER SIDDELEY DYNAMICS LIMITED, a British Company of Manor Road, Hatfield, Hertfordshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electrically controlled air conditioning and pressurisation systems, especially for aircraft cabin areas.

Existing systems for controlling the cabin temperature of high speed, high altitude aircraft, have reached a stage which is typified by a system that utilises a tapping from the compressor area of a turbine prime mover to provide a hot air supply for pressurising the cabin areas, this air supply being passed through one or more heat exchange means to reduce the temperature. From this point the air which is still hot has two alternative paths, one path forming a bypass, under the control of electro-mechanical valve means, which delivers hot air to the cabin area directly. The other path directs the air supply to a turbo-compressor cold air unit and final heat exchange means that reduces the air temperature possibly to freezing point or below. Air from the cold air unit is then mixed with the hot air from the valved bypass stream to obtain the required temperature in the cabin area.

This form of conditioning system is normally controlled in an automatic manner by sensors mounted in the inlet ducts and cabin that register the cabin temperature, this temperature being compared by algebraic summing apparatus with that set on a cabin temperature selector and any resulting difference signal being used to open or close the electro-mechanical valve in the bypass stream. If, for any reason, the automatic control fails the bypass valve may be opened or closed by switch means within the cabin area to manually set the temperature.

A control system such as that described above has deficiencies in either the automatic mode of operation or when malfunction demands the use of the manual mode of control. The automatic control is deficient generally for the following reasons. The electro-mechanical valve normally used does not have the necessary power to operate fast enough to offset the rapid changes encountered, e.g. typical operating times are 20 to 60 seconds. The control system normally used attempts to maintain a selected cabin area bulk temperature by adjusting the cabin inlet duct temperature according to need, and cabin inlet duct limits are imposed to avoid duct overheating, or duct icing, the lower limit being conventionally set just above the freezing point of water at 0°C. It has been found that with rapid engine accelerations from idle resulting in a rapid increase of pressure differential across the expansion turbine in the final cooling unit, there is still a tendency for the duct temperature to drop below the 0°C limit before the slow acting temperature control valve can compensate. This, in certain conditions, allows ice to form in the duct with possible subsequent damage. Similarly, with rapid engine accelerations in the higher region of engine speed, if the heating mode is selected, overshoots in duct temperature can occur and when the temperature is in excess of the duct upper limit the duct could be damaged or the system automatically shut down.

The manual mode of control is deficient generally for the following reasons. The slow positioning of inching of the electro-mechanical valve under manual control does not operate fast enough to offset the rapid changes in the system. A crew member attempting to crudely adjust the inlet duct temperature in order to maintain comfort gives very poor control of duct tem-

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perature and does not compensate for subsequent engine speed surges and aircraft speed and altitude changes, all of which have marked effects on the system temperature. This mode of control also causes considerable crew workload and in many cases fatigue, which may lead to a system cut-out or damage, as in this mode no effective duct temperature limit control is possible.

The invention seeks to overcome these problems by providing an improved control system in both the automatic mode and the manual mode of control. An object of the invention is to achieve a system operating fast enough to offset fully the rapid changes encountered in modern aircraft.

According to the present invention, there is provided a vehicle air conditioning and pressurisation system, especially for aircraft cabins, in which air bled from the turbine of a gas turbine prime mover is delivered via heat exchange means to a cabin space, the air delivery path including a turbo-compressor cooling unit and a valve-controlled bypass around this unit, and the valve being controlled automatically in response to signals from temperature sensors in the air delivery duct and the cabin, and wherein the valve is an electro-pneumatic (or fast-acting electro-mechanical) valve and is arranged to respond to electrical signals from an electrical controller that in turn receives signals not only from said temperature sensors but also from a water detector or ice anticipator sensor located in the re-combined air flow path downstream of the cooling unit and the bypass and upstream of a water extractor through which the re-combined air flow passes before delivery to the cabin, this further sensor serving to provide early warning and prevent ice formation in the air duct.

The invention will be more clearly understood with reference to the following description of one embodiment, given by way of example and with reference to the accompanying drawing which is a diagram of the temperature control system to be described.

In the drawing, a hot air supply A is tapped from the compressor region 1 of a gas turbine prime mover 2. Air supply A passes through a shutoff valve 3 and a pressure reducing valve 4 before passing through one or more heat exchangers 5 employing ram air, i.e. the external ambient air flow, as a cooling fluid. Beyond this, the air A at approximately 150°C. is split, one path leading through an electro-pneumatic high speed valve 6 and back to a cabin inlet duct D. The alternative path B feeds the air through a cold air unit, which comprises a compressor stage C, final heat exchanger means 7 also employing ram air as a cooling fluid, and an expansion turbine stage T which drives the compressor stage. The outlet from the turbine stage T connects to the cabin inlet duct D and the recombined flows pass through a water extractor E before entering the cabin area F. The system is provided with a number of sensors, one being a water detector or ice anticipator mounted at I upstream of the water extractor E to detect the incipient formation of ice. Other temperature sensors are provided downstream of the extractor E at G and H and there are also cabin sensors J. The purpose of these sensors is to control automatically the operation of the valves 3 and 6 via an electrical control unit 10.

The electro-pneumatic valve 6 is capable of extremely fast actuation and operation, in the order of 1 second or below, from the fully open to the fully closed position, thus being faster than the system change due to engine throttle opening since the turbine prime mover takes approximately 3 seconds to run up from idle to maximum revolutions. As in conventional systems the automatic control gear attempts to maintain a selected cabin bulk temperature according to need. Again cabin inlet duct limits are imposed, to avoid duct overheating, or duct icing, but here a lower limit may be set that can be considerably below the figure just above 0°C. of previous systems, by makin use of the ice anticipator sensor I. In dry tropical climates there are often considerably enhanced cooling possibilities and this system can make use of inlet duct air at a temperature just above the duct ice-point rather than just above 0°C. With rapid turbine prime mover accelerations from idle, resulting in a rapid increase of pressure differential across the expansion turbine T, there is often a tendency for the temperature of the cabin inlet duct D to fall below the duct ice-point. The ice-anticipator I in conjunction with the fast response valve 6 can prevent this happening and back the system off to just above the ice-point, which might be as low as −15°C. Similarly, with rapid engine acceleration in the higher engine speed zone the chance of avoiding duct overheat overshoots is considerably improved due to the rapidity of response of the system.

The manual mode of operation in the conventional type of system is replaced by a standby operational mode in which the system functions in much the same way as in the automatic control mode. Thus where the sensor H is used to regulate the temperature in conjunction with the cabin sensor J in the automatic mode, the sensor G is used in the standby mode to regulate the inlet duct temperature, the thermostatic

temperature setting being selected manually by a duct temperature selector 11 within the cabin area. The controlling crew member therefore no longer "inches" a control valve but actually selects a specific duct or cabin inlet temperature according to comfort requirements. The system then maintains the selected duct temperature irrespective of engine speed and aircraft flight variations, with the valve 6 compensating effectively for such variations due to its rapidity of operation. The new mode of control can control steadily and accurately within any duct temperature limitations which may be desirable, and in the event of failure of the automatic mode of control, the aircraft crew are still able to maintain a high degree of cabin temperature comfort with a minimum increase in the crew monitoring workload and a minimum risk of cut-out or system damage.

WHAT WE CLAIM IS:—

1. A vehicle air conditioning and pressurisation system, especially for aircraft cabins, in which air bled from the turbine of a gas turbine prime mover is delivered via heat exchange means to a cabin space, the air delivery path including a turbo-compressor cooling unit and a valve-controlled bypass around this unit, and the valve being controlled automatically in response to signals from temperature sensors in the air delivery duct and the cabin, and wherein the valve is an electro-pneumatic (or fast-acting electro-mechanical) valve and is arranged to respond to electrical signals from an electrical controller that in turn receives signals not only from said temperature sensors but also from a water detector or ice anticipator sensor located in the re-combined air flow path downstream of the cooling unit and the bypass and upstream of a water extractor through which the re-combined air flow passes before delivery to the cabin, this further sensor serving to provide early warning and prevent ice formation in the air duct.

2. A system for an aircraft cabin according to Claim 1, wherein the heat exchanger means comprise at least one heat exchanger upstream of the bypass and cooling unit, and at least one further heat exchanger between the compressor and turbo-expander of the cooling unit, these heat-exchangers being cooled by flows of ram air.

3. A system according to Claim 1 or Claim 2, wherein the temperature sensors include at least one sensor in the air duct downstream of the water extractor.

4. A system according to claim 1 or Claim 2 or Claim 3, wherein in the event of a failure the system operates in a standby mode wherein the air delivery temperature is thermostatically regulated by the response of the electro-pneumatic bypass valve to a temperature sensor in the duct downstream of the water extractor, the thermostatic temperature setting being selectable manually in the cabin.

5. A system according to any one of the preceding claims, wherein the electrical controller also controls a valve upstream of the heat exchanger means and of the cooling unit and bypass.

6. An air conditioning and pressurisation system for an aircraft cabin, substantially as described with reference to the accompanying drawing.

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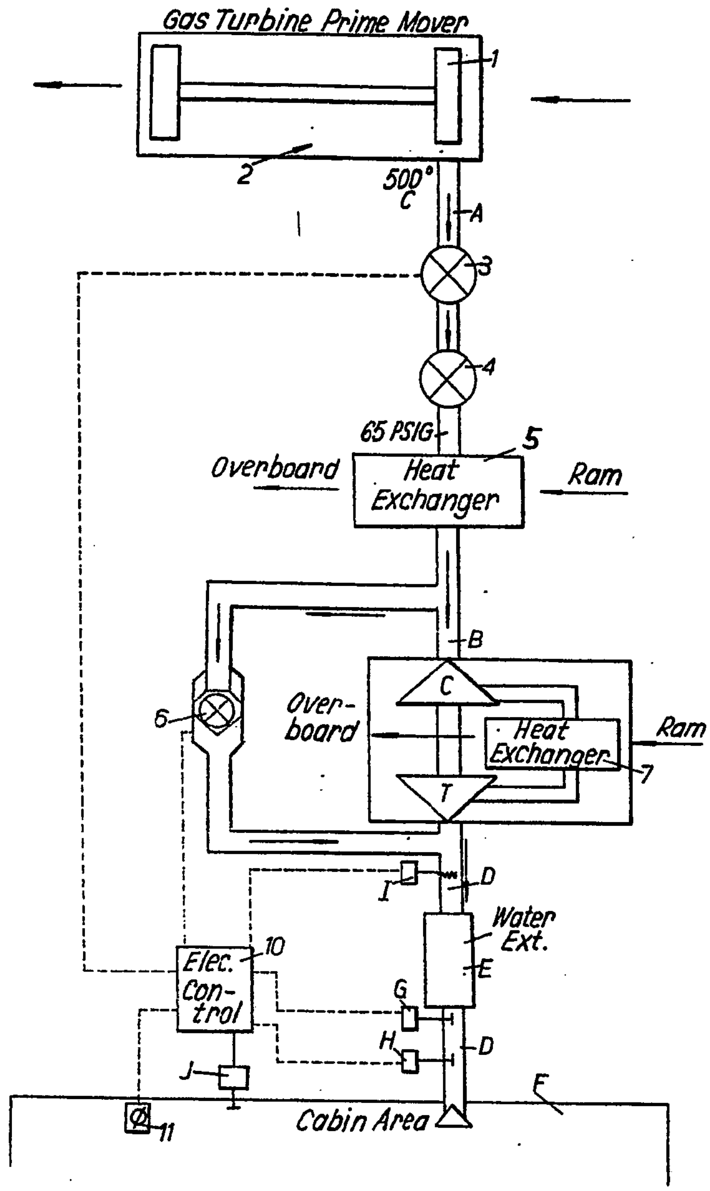
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Cabin Area